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The Aileron Power and Roll Damping of the R.T.V.2 as determined from Flight Measurements

by

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SUMMARY

The roll motion of an R.T.V.2 has been analysed to determine the aileron power and roll damping of the R.T.V.2 over a range of Mach numbers. The results of this analysis together with some theoretical extrapolation of the results are presented.

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1 Introduction

In order to obtain flight measurements of the aileron power and roll damping of the R.T.V.2 ailerons, R.T.V.2 round 8 (Trial PR2/C/1, round 1) was fired with a programme of aileron deflections on two ailerons. Roll velocity and aileron angles were measured throughout the flight using the R.A.E. 465 m.c.s. sub-miniature telemetry system. The roll attitude of the vehicle was also measured, both by camera observations and the 465 m.c. roll telemetry system.

The variations of aileron deflection, roll velocity and roll attitude with time were analysed to obtain the aileron power and roll damping of the R.T.V.2 over a range of Mach numbers and the results of the analysis are presented in this paper. A more detailed account of the results of the trial, the method of analysis employed and the analysis of the trials data will be given in a future R.A.E. Technical Note.

2 Determination of Aileron Power and Roll Damping

The equation of motion of a rolling projectile is taken to be:-

$$A\dot{p} - p\,L_p = \zeta\,L_\zeta + L_0 = T \qquad (1)$$

where
A = projectile moment of inertia in roll
p = roll angular velocity
L_p = roll torque per unit rate of roll
ζ = aileron deflection
L_ζ = roll torque per unit aileron deflection
L_0 = roll torque due to misalignments
T = total roll torque due to aileron deflection and misalignments.

Roll velocity and aileron deflection were measured continuously during flight, a programme of deflections of two ailerons being used.

The programme was:-

t	=	0	to	t	=	0.5 sec.	ζ =	$+2.5^\circ$
t	=	0.5	to	t	=	1.0 sec.	ζ =	-2.5°
t	=	1.0	to	t	=	1.5 sec.	ζ =	$+2.0^\circ$
t	=	1.5	to	t	=	2.0 sec.	ζ =	-2.0°
			et. seq.					

In order to check the calibration of the rate gyroscope used to measure roll velocity, the recorded roll velocity was integrated with respect to time to give change in roll attitude. This estimate of the change in roll attitude was then compared with the roll attitude obtained from camera and roll telemetry observations. The measurements of roll attitude obtained from camera and roll telemetry observations were in good agreement with each other, and were assumed to be subject only to random, i.e. non systematic error. With this assumption, the comparison of the integral of recorded roll velocity, and the observed roll attitude enabled

a scale error ($\delta\omega$) and zero error 1.2 rad/sec on the records of the roll velocity to be removed. This procedure allowed the scale of the records of the roll-velocity gyroscope to be obtained to an accuracy of rather better than $\pm 4\%$.

Using the corrected values of the roll velocity the following principle was used to determine the aileron power and roll damping, from records of roll velocity.

It is assumed that during a period of time, Δt say, when ζ is constant, L_p, L_ζ, L_o, are also constant. With these assumptions integrating equation (1) over a finite period of time δt, we obtain

$$A(p_{t+\delta t} - p_t) - L_p \int_t^{t+\delta t} p\,dt = T\,\delta t \qquad (2)$$

Thus during the period of time Δt, plotting $p_{t+\delta t} - p_t$ against $\int_t^{t+\delta t} p\,dt$ for different values of t, but keeping δt constant we obtain a straight line of slope $\frac{L_p}{A}$, and intercept $\frac{T}{A}\delta t$ when $\int_t^{t+\delta t} p\,dt = 0$.

In practice the definite integral $\int_t^{t+\delta t} p\,dt$ can be evaluated with sufficient accuracy by using a trapezoidal summation, providing the time interval between successive values of p used in the summation is small compared with $\frac{A}{L_p}$.

The values of p obtained from R.T.V.2 round 8, when treated in this way did in fact give good straight lines, and from these lines, L_p, and T were obtained. As a symmetrical aileron programme was used L_o could be eliminated from alternate values of T, and L_ζ and L_p determined.

The value of L_o is equivalent to 1° of aileron deflection on two ailerons.

Figs.2 and 3 give ℓ_ζ and ℓ_p as functions of Mach number, where

$$\ell_\zeta = \frac{L_\zeta}{\frac{1}{2}\rho v^2\,dS}\ ; \qquad \ell_p = \frac{L_p}{\frac{1}{2}\rho v\,d^2S}\ ;$$

S = body maximum cross-sectional area = 1.576 ft^2;

d = body maximum diameter = 1.417 ft.

Computed values of L_ζ and L_p obtained from the experimental data are plotted in figures 4 and 5 respectively, as functions of Mach number and height, tables of the 'I.C.A.N.' standard atmosphere being used to obtain the variation of $\frac{1}{2}\rho v^2$, and $\frac{1}{2}\rho v$ with Mach number and height.

3 Discussion of Results

Considerations of the errors in the experimental data suggest that ℓ_ζ and L_ζ are accurate to about ±7% and ℓ_p and L_p are accurate to about ±15%.

3.1 Aileron Power

In Fig.2, the experimental values of ℓ_ζ, together with theoretical estimates of the values of ℓ_ζ are shown.

The theoretical values were obtained by calculating the lift on the ailerons, assuming full root loss at the junction of the ailerons with the body, but ignoring any interaction of the ailerons with each other.

Now the slender body value of the aileron power, assuming $\frac{\partial C_N}{\partial \zeta} = \frac{\pi A\!\!R}{2}$, for each aileron where $A\!\!R$ is the aspect ratio of each aileron, and no interaction between the ailerons is $\ell_\zeta = -22.5$, whereas the corresponding value of ℓ_ζ determined experimentally i.e. at $M = 1$, is 14.5. Further, the experimental values of ℓ_ζ appear to tend towards the theoretical values at $M = 1.4$.

It is believed that the tendency for the experimental results to be below the theoretical results at the lower Mach numbers, but to approach them at the higher Mach numbers is due to interaction between each aileron and the two at right angles to it.

It will be shown in a future R.A.E. Technical Note that such an interaction is geometrically possible at Mach numbers less than approximately 1.5. This loss of aileron power has been noted elsewhere[2].

3.2 Roll Damping

The experimental variation of ℓ_p with Mach number is shown in Fig.3.

The R.T.V.2 wings are cropped delta-wings with a net span of 44.8", root chord of 51.6" and tip chord of 29.2", the leading edge being swept back at 45°. It is difficult to estimate ℓ_p theoretically for such wings for the range of Mach numbers covered by the experiment, but slender-body theory does enable us to estimate ℓ_p for $M = 1.0$, the theoretical values being shown in Fig.3. The lower value is that for the wings alone, and the upper value is for the wings and tail, assuming that the tail is 50% effective.

As can be seen from Fig.3 the experimental values of ℓ_p lie between these two values.

REFERENCES

No.	Author	Title, etc.
1	J.D. Burgess	Drag coefficient of R.T.V.2 with wrap-round boosts, derived from flight measurements R.A.E. Tech. Note No. GW 224, Dec. 1952
2	-	Handbook of Supersonic Aerodynamic data, applicable to Guided Weapon design GW/Handbook/1 Section 4.2.0

Attached:

Drawings GW/P/4691 to 4695

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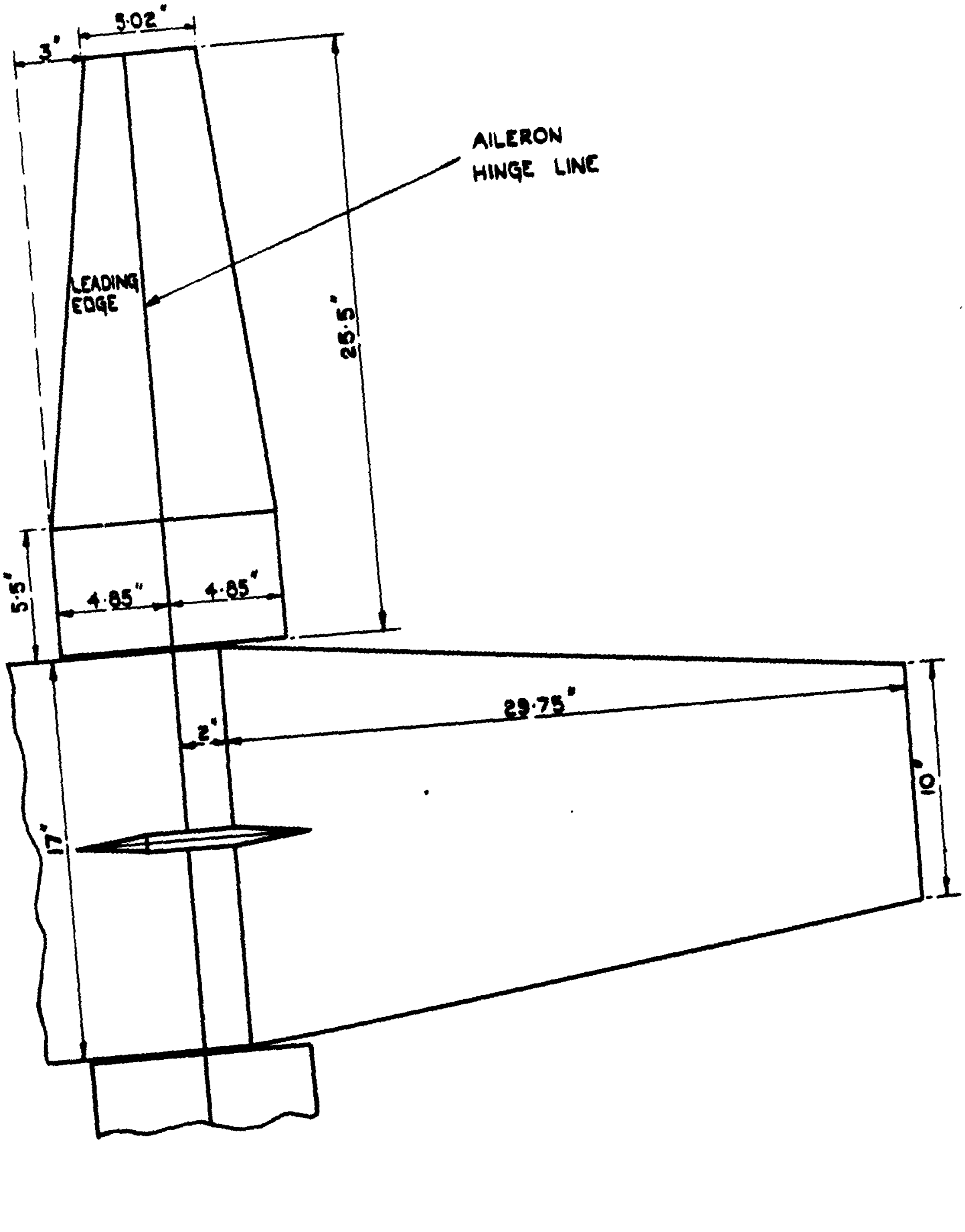

FIG. 1. DIMENSIONS OF THE R.T.V. 2 AILERON.

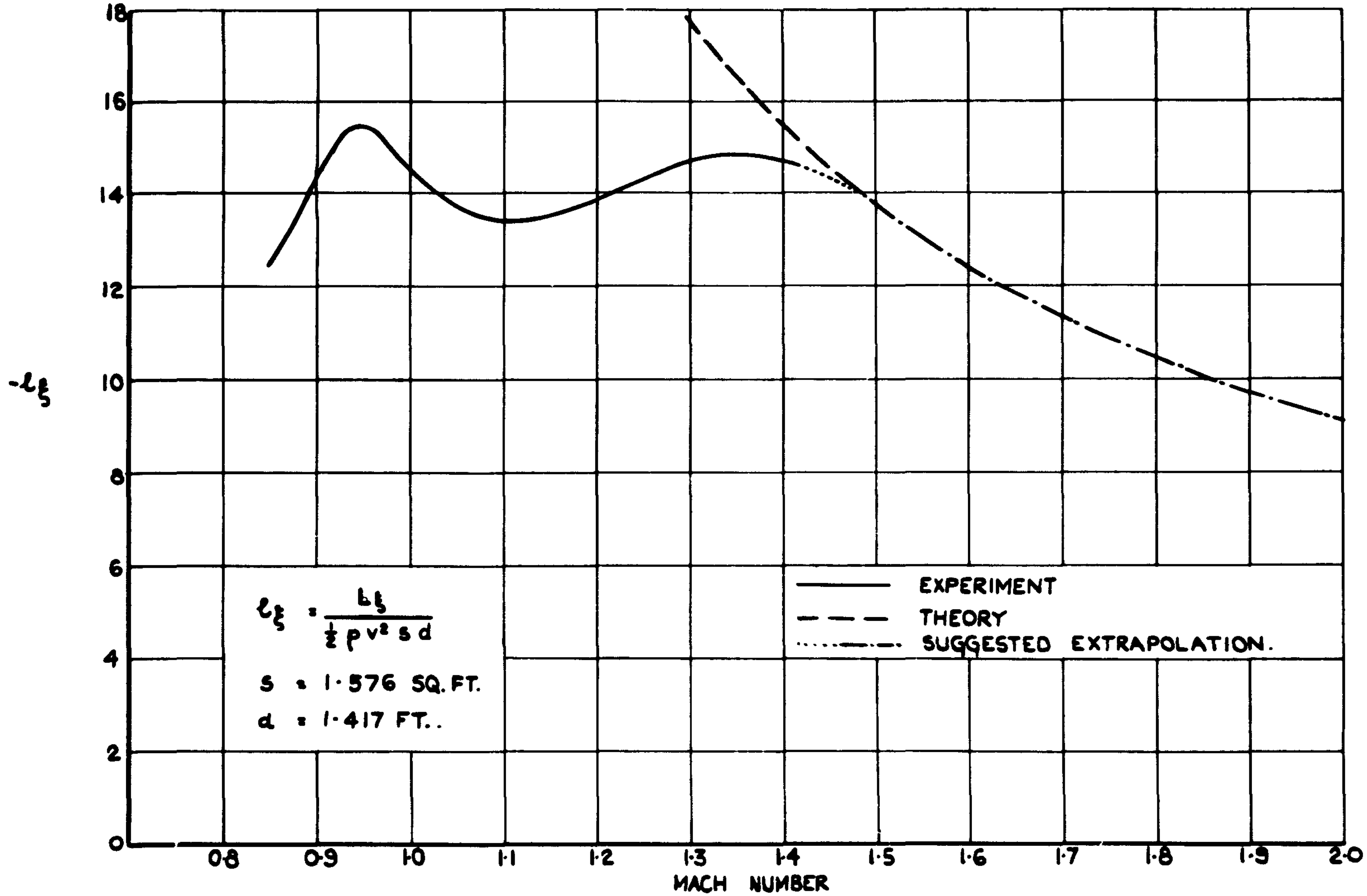

FIG.2. R.T.V. 2. VARIATION OF ℓ_ξ WITH MACH NUMBER. (FOUR AILERONS.)

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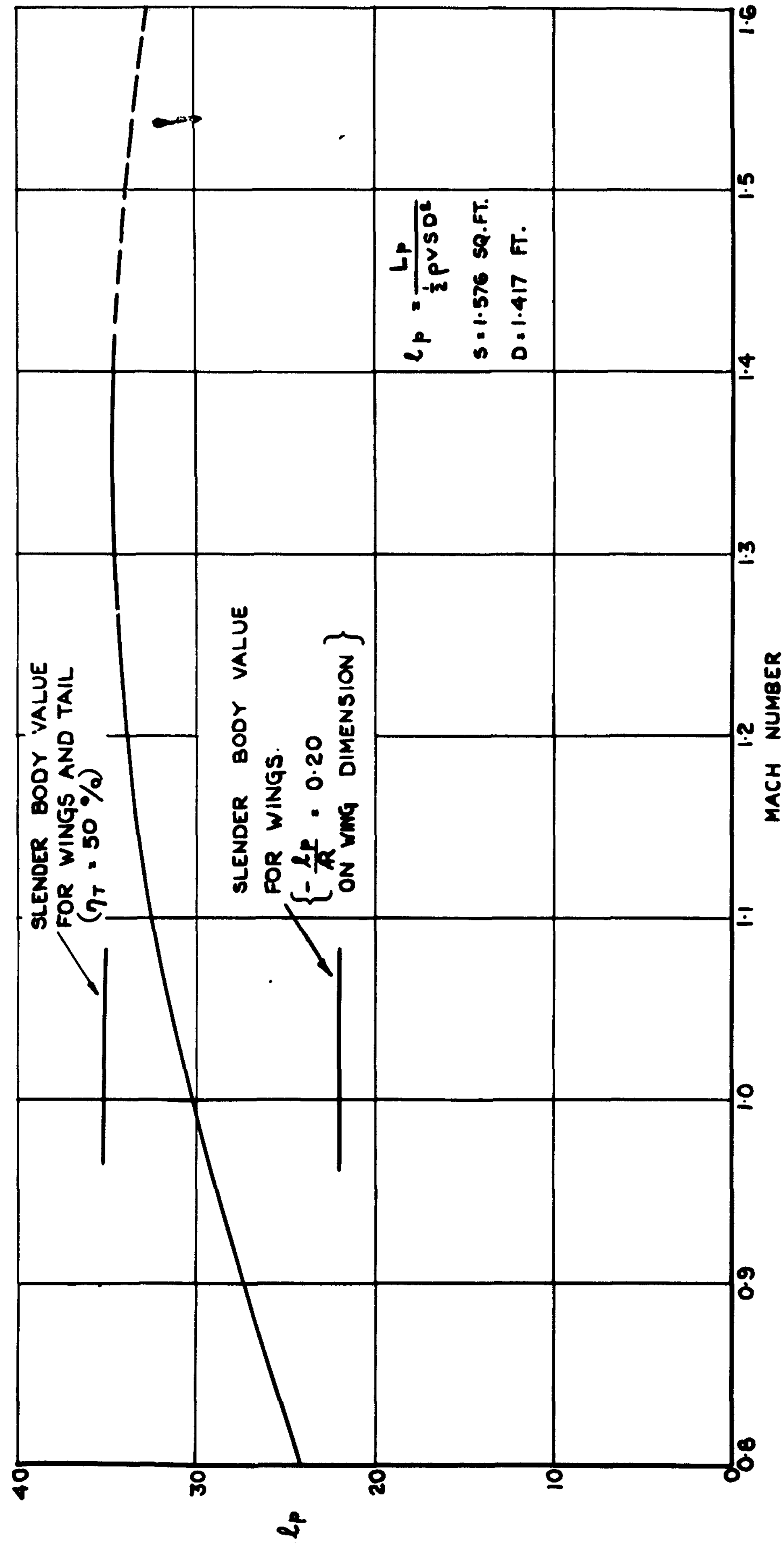

FIG. 3. R.T.V. 2. VARIATION OF ℓ_p WITH MACH NUMBER.

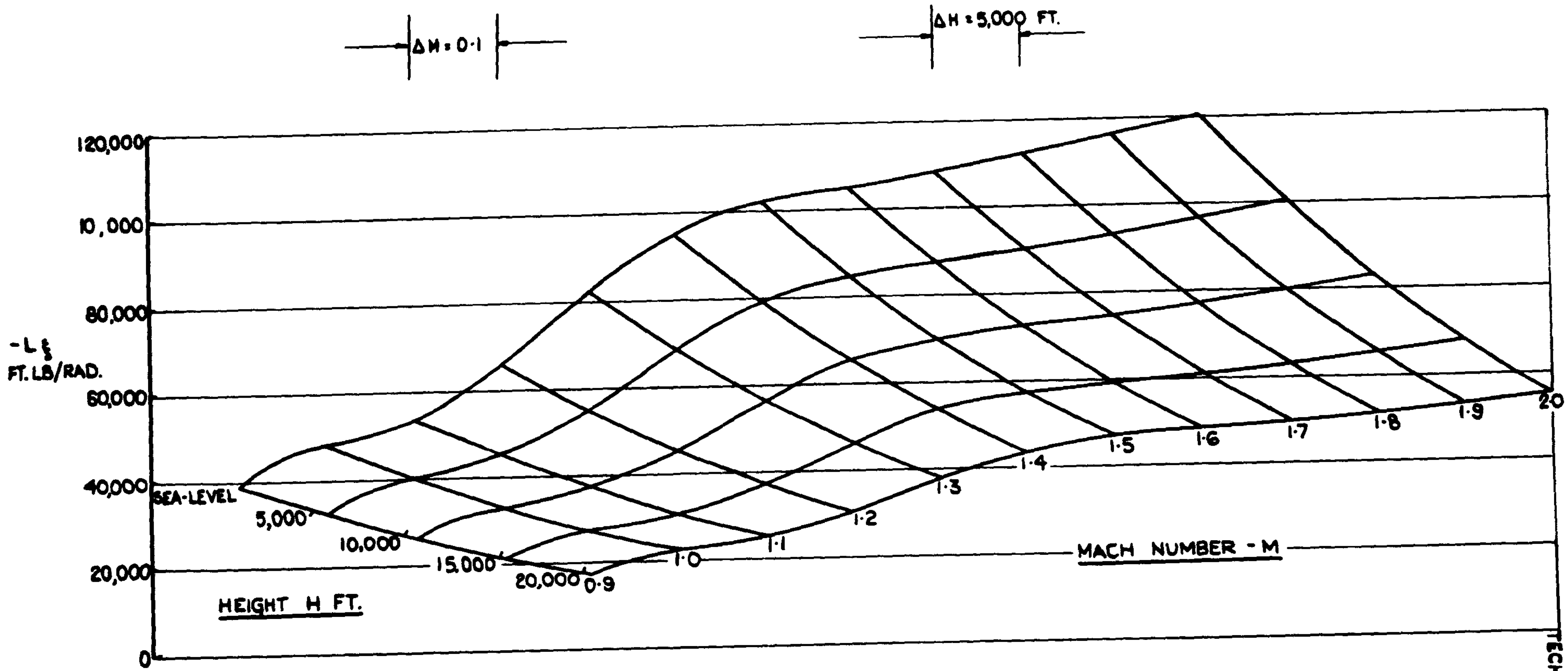

FIG. 4. R.T.V. 2. VARIATION OF L_ξ WITH HEIGHT AND MACH NUMBER.
(FOUR AILERONS.)

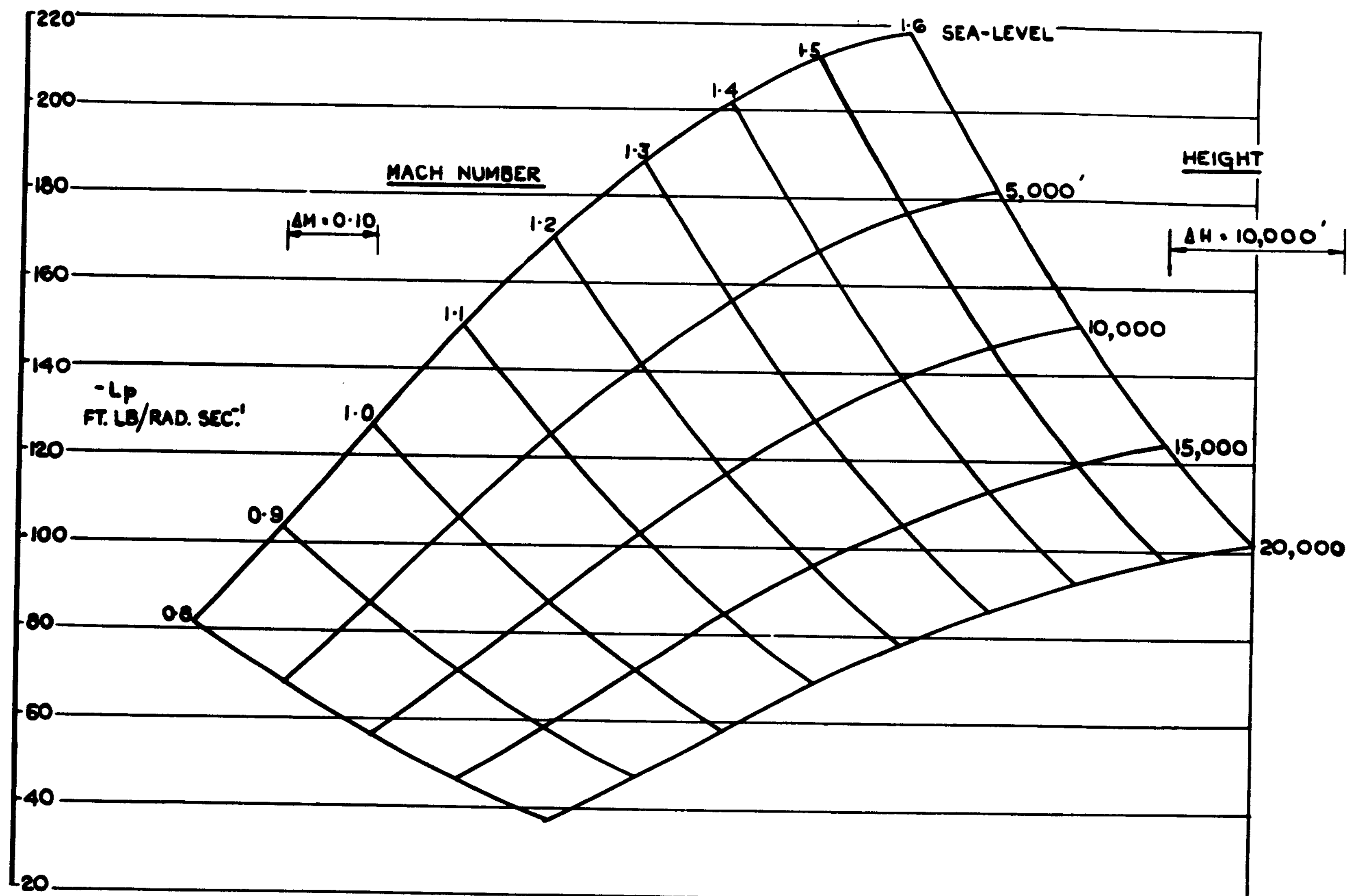

FIG. 5. R.T.V. 2. VARIATION OF L_p WITH HEIGHT AND MACH NUMBER.

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